8

Trends and Problems of High-level Radioactive Waste Disposal Projects — Technical and Social Aspects —

RYOTA OMORI
Environment and Energy Research Unit

8.1 Introduction

One of the issues concerning the rights and wrongs of nuclear power generation is the problem of high-level radioactive waste disposal. This problem has greatly awakened the public's interest, and it has been discussed among the people not only from the technical aspect, but also from other views including repository sites, environmental ethics such as generations' equal responsibility for environmental loads, and the non-proliferation of nuclear weapons.

High-level radioactive wastes are inevitably generated in nuclear power plants. It is considered that the appropriate disposal of these wastes is the responsibility of the generations enjoying the benefits from the nuclear power generation industry. The 7th Technology Foresight[1] published by the National Institute of Science and Technology Policy in 2001 ranked third in "importance" the subject "Commercialization of solidification disposal technologies for high-level radioactive wastes" among 1,065 topics in 16 fields

Today, the world's nuclear power interests are paying much attention to whether or not the Yucca Mountain site in the U.S. will be selected for a geological repository. This site is the only candidate for a high-level radioactive waste repository in the country. For about 15 years, the Department of Energy (DOE) and other organizations made design and safety assessments for the prospective repository to be installed in this site. Finally in February 2002, DOE Secretary Abraham recommended the Yucca Mountain site for the final repository to President Bush. President Bush approved this site, and recommended it to Congress. In Nevada, however, the local people expressed deep-rooted opposition to the repository construction project in the Yucca Mountain site. Early in April, Governor Gwyn filed his disapproval with Congress, as most people expected.

To overturn Governor Gwyn's disapproval, the House and Senate needed to pass President Bush's approval. On the 8th of May, the House approved the Federal Government's decision. The Senate will vote on this measure in July at the latest. However, the result cannot be forecasted, because the number of seats in the Senate supporting the Government's decision is almost equal to that of the opposition. If the Senate approves this measure, the DOE will file its application for a license with the Nuclear Regulatory Commission (NRC). If the Senate rejects this measure, the project will start with a clean slate.

In Japan, the "Law on Final Disposal of Specified Radioactive Waste" was enacted in May 2000, and, under this Law, the Nuclear Waste Management Organization of Japan (NUMO) was established as the main disposal project implementation organization (hereinafter referred to as the "implementation organization") in October 2000. To select its repository, the NUMO will start public invitation of candidates for preliminary survey sites in the 2002 fiscal year as scheduled.

This report describes the domestic and foreign trends of high-level radioactive waste disposal projects, and discusses the technical and social aspects of this problem from various points of view, especially focusing on the aspect of scientific and technological frontier researches as a part of the research and development for HLW disposal technologies, and on the social aspect represented by site problems.

8.2 High-level radioactive wastes and the disposal options

This chapter summarizes basic information about high-level radioactive waste disposal.

In nuclear power plants, uranium oxide fuels are generally replaced about three years after reactors are charged with them. Table 1 indicates that the spent fuel contains: uranium 238, accounting for a greater part; uranium 235, left not fissioned; fission products derived from the fission of uranium 235; and plutonium and other actinides produced from uranium 238.

Today, Japan and France have adopted the policy of recovering uranium and plutonium by reprocessing spent fuels to improve the efficiency of uranium resource utilization. Plutonium, especially, has such a high value of utilization for energy that it is mixed with uranium to produce the mixed-oxide fuel (MOX) used for light water reactors, and is expected to be used as the fuel for fast breeders in the future. On the other hand, fission products and actinides are vitrified and sealed up in stainless steel containers. These vitrified waste forms are called high-level radioactive wastes[Note] and have the highest radioactivity level among all the wastes derived from nuclear power generation. Because they contain long-lived nuclides, they require a very long-term control and disposal system.

On the contrary, the US and Sweden have adopted the policy of directly disposing of spent fuels without reprocessing them. In this case, spent fuels themselves are treated as high-level radioactive wastes. Unless otherwise specified, vitrified waste forms from the spent-fuel reprocessing process as well as spent fuels to be directly disposed of are referred to as high-level radioactive wastes in this article.

Representing international consensus, from the viewpoints of technological reliability and waste producers' responsibility, the most appropriate disposal method for high-level radioactive wastes is geological disposal, where the wastes are buried in strata at a depth of several hundred meters below the ground. In addition to geological disposal, various methods have been proposed, including seabed disposal, ice-cap disposal within the Antarctic Circle, and space disposal using rockets. However, seabed disposal and ice-cap disposal are prohibited under international treaty, and cosmic disposal faces problems such as the technological reliability of rocket launching. Therefore, this article will discuss only geological disposal hereinafter.

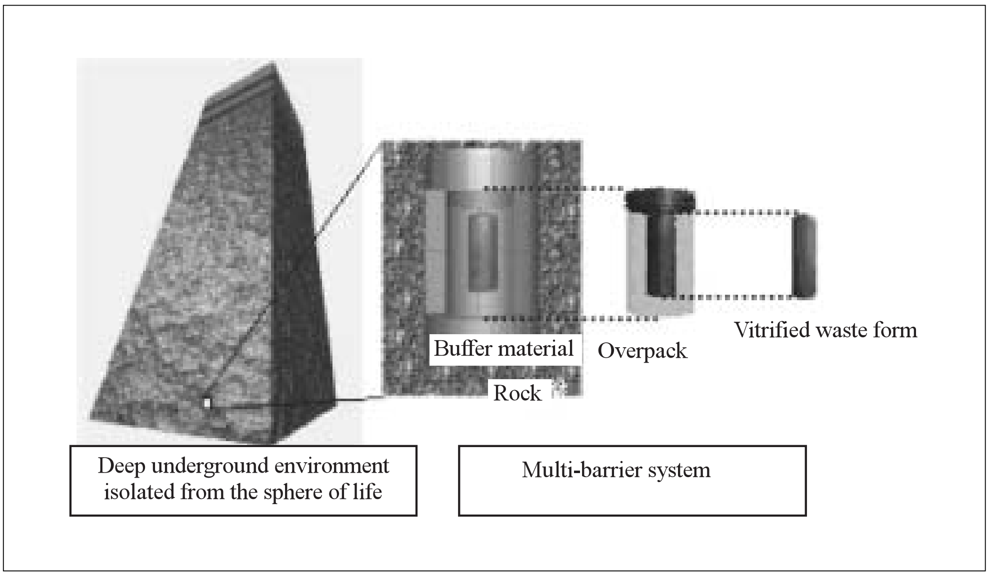
Figure 1 shows a typical model of a geological disposal system as proposed in Japan. In this figure, radioactive nuclides are isolated from the sphere of life by: a vitrified form; a stainless steel overpack; artificially installed barriers — engineered barriers — such as impermeable buffer materials (ex., bentonite); and the surrounding rocks — natural barriers — having the functions of adsorbing and diffusing

Table 1: Examples of new and spent fuel compositions and spent fuel processing methods

<table>
<tr><th rowspan="2"></th><th colspan="2">Fuel Composition (% in weight)</th><th colspan="2">Spent Fuel Processing Method</th></tr>
<tr><th>New fuel</th><th>Spent fuel</th><th>Direct disposal</th><th>Reprocessing</th></tr>
<tr><td>Uranium 238</td><td>Approx. 97</td><td>Approx. 95</td><td rowspan="4">Geological disposal</td><td rowspan="3">Recovery and reuse for nuclear fuel</td></tr>
<tr><td>Uranium 235</td><td>Approx. 3</td><td>Approx. 1</td></tr>
<tr><td>Plutonium</td><td>0</td><td>Approx. 1</td></tr>
<tr><td>Fission products and actinides</td><td>0</td><td>Approx. 3</td><td>Vitrification and geological disposal</td></tr>
</table>

Note: In the strict definition, "high-level radioactive wastes" include not only vitrified waste forms, but also the solutions to be vitrified. "Specified radioactive waste" as used in the "Law on Final Disposal of Specified Radioactive Waste" means vitrified wastes.

Figure 1: Model of a geological disposal system [2]



radioactive nuclides (namely, a defense-in-depth system). It should be noted that the design of a geological disposal system, like that shown in Figure 1, largely depends on the country's policy, especially whether or not spent fuels are reprocessed.

8.3 Domestic and foreign high-level radioactive waste disposal projects

Table 2 shows the high-level radioactive waste disposal methods used, the implementation bodies, and the scheduled start time of operations in Japan and other countries.

(1) Japan

The total number of vitrified waste forms containing spent fuels produced by the operation of nuclear reactors for power generation was 13,300 before the end of 1999, and is expected to reach about 40,000 by 2020.[4] It should be noted that about 30 vitrified waste forms are produced by one-year's operation of a nuclear power plant having an output of 1 million kW.

In 1999, the Japan Nuclear Cycle Development Institute (JNC) prepared the "H12: Project to Establish the Scientific and Technical Basis for HLW Disposal in Japan — Second Progress Report on Research and Development for the Geological Disposal of HLW in Japan"[5] (hereinafter referred to as the "H12 Report") by compiling the past results of geological disposal researches, and submitting it to the Japan Atomic Energy Commission (JAEC). The Commission reviewed the H12 Report, and concluded that the Report proved the technical reliability of geological disposal and provided the technical bases on which the Commission should select the projected disposal sites and establish safety

Table 2: High-level radioactive waste disposal projects by country [3]

Country	Disposal Option	Implementation Organization	Scheduled Start of Operation
Japan	Vitrification	Nuclear Waste Management Organization of Japan (NUMO)	Within 2033 to 2037
U.S.	Direct disposal	Department of Energy (DOE)	2010
Finland	Direct disposal	POSIVA	2020
Sweden	Direct disposal	Nuclear Fuel and Waste Management Company (SKB)	2015: Preliminary 2023: Normal
France	Vitrification	Agence nationale pour la gestion des Déchesradioactifs (ANDRA)	Not scheduled
Germany	Direct disposal & Vitrification	Federal Radiological Protection Agency (BfS)	Around 2030

standards.[6]

Based on the H12 Report, the "Law on Final Disposal of Specified Radioactive Waste" was enacted in May 2000 (and promulgated in June 2000). This Law provides for the basic framework necessary to implement high-level radioactive waste disposal projects. Under this Law, the Nuclear Waste Management Organization of Japan (NUMO) was established as the implementation organization for HLW disposal projects in October 2000.

The Japanese Government will prepare the safety review guidelines, based on the future results of researches made by JNC and other organizations. The NUMO will undertake works to select the "preliminary survey sites", "detailed investigation sites" and "construction site for the final repository" in turn. The final disposal repository is scheduled to start operation within the period of 2033 to 2037.[7]

(2) The US

Under the amendment of the Nuclear Waste Policy Act in 1987, the Yucca Mountain site adjacent to the Nuclear Weapons Test ground in Nevada was designated as the only repository candidate. The US Department of Energy (DOE) has undertaken design and performance, environmental impact and other assessments of repository facilities to be installed in this site.[8, 9]

Finally in February 2002, DOE Secretary Abraham recommended this site as the repository to President Bush, as described earlier in this article. President Bush then accepted this site, and recommended it to Congress. In Nevada, however, the local people expressed deep-rooted opposition to the repository construction project in the Yucca Mountain site. Early in April, Governor Gwyn filed his disapproval of President Bush's decision with Congress.

To overturn Governor Gwyn's disapproval, the House and the Senate had to vote on this measure within 90 days. On the 8th of May, the House passed the Government's decision by an overwhelming margin of 306 to 117 votes. The Senate will vote in July at the latest. However, the result cannot be forecasted, because the Democratic Party now dominates the Senate, and because Majority Leader Daschle and Floor Leader Read of the Democratic Party are in the forefront of opposition to this project.

If the Government's decision passes the Senate, the DOE will apply for an operation license with the NRC. After the obtainment of the license and the construction of the repository facilities, it is expected that the repository will start operation in 2010 at the earliest. The repository will receive about 77,000 tons of high-level radioactive wastes (of which the greater part is spent fuels from commercial reactors) for about 25 to 30 years after it has started operation. Performance assessment monitoring will continue to be implemented after the reception of HLW has been completed. The repository will be closed in the 2110s. If the Senate rejects the Government's decision, this project will start with a clean slate.

(3) Europe

High-level radioactive disposal projects are making rapid progress especially in Finland and Sweden.

Finland is the only country where the Congress approved a candidate repository site. In May 1999, POSIVA, a private company as the implementation organization, made an application to the Government for the "Decision in Principle" that the Olkiluoto district, about 200 km northwest of Helsinki, is to be selected as the final disposal site. In May 2001, the Finnish Congress approved the "Decision in Principle" after approval by the local assembly and the Government. At this site, POSIVA plans to start underground rock surveys in 2003, and the construction and operation of a repository in 2010 and 2020, respectively.

In Sweden, the implementation organization is SKB, a nuclear fuel and waste management company. In November 2001, the Swedish Government approved the site characterization surveys to be conducted by SKB at 3 points in the country. The local governments in Oskarshamn and Östhammar officially expressed their acceptance of the respective surveys. In April 2002, however, the local government in Tieölp rejected any type of survey to be made there. SKB plans to finally select a repository site by 2007, and start normal operation of the constructed repository by 2023. The project by SKB is characterized by the two-phase approach in which a full-scale repository is constructed after a 5 to 10% smaller-sized plant has been completed for the purpose of technical demonstration.

In France, ANDRA, a radioactive waste management organization, filed its application with the Government in 1996 to obtain licenses to construct and operate underground research centers at 3 sites. In 2000, construction of an underground research laboratory (URL) started at Bure. However, the Government rejected the projects at the 2 other sites. Following this, ANDRA started to conduct site characterization surveys at 15 granite sites in order to construct the second underground research center. However, these surveys have been halted because of the local people's opposition.

In Germany, an underground environment characterization survey had been conducted at Gorleben in the state of Nieder Sachsen since the 1980s. In 2000, however, an agreement was concluded between the Federal Government and electric power companies for the secession from the nuclear power industry. Thus, it was decided under this agreement that the characterization survey at this site should be suspended for 3 to 10 years to "identify problems regarding the repository concept and safety technologies."

8.4 Various aspects of the high-level radioactive waste disposal problem

As described earlier in this report, there are various issues concerning the high-level radioactive waste disposal problem. This complicatedness in the social aspect of this problem is one of the remarkable characteristics that high-level radioactive waste disposal technologies or, more generally, nuclear power technologies present. This chapter discusses the high-level radioactive waste disposal problem in the 4 aspects shown in Figure 2.

(1) Vital nuclear power generation technology

High-level radioactive wastes are inevitably produced by the operation of nuclear power plants, whether spent fuels are directly disposed of or reprocessed.

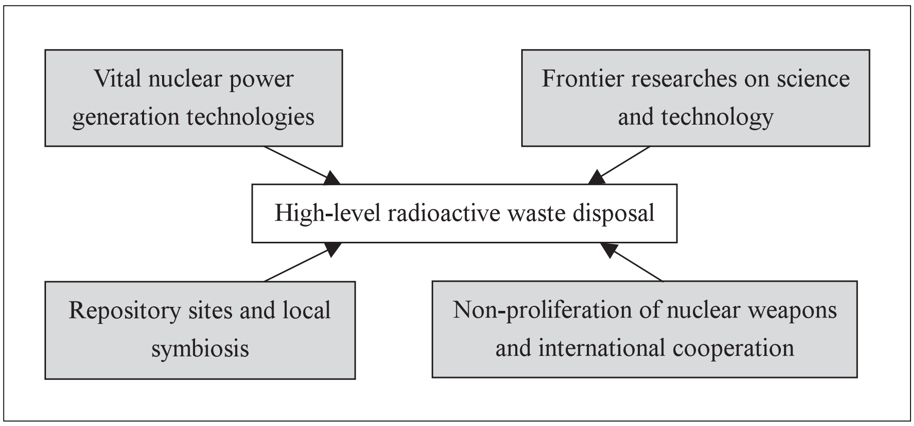
As of the end of 2000, about 430 nuclear power plants were under operation throughout the world, and nuclear power accounted for about 7% of the total primary energy production. Today, however, geological disposal of high-level radioactive wastes has yet to be implemented in any country, and the accumulated wastes are stored in ground facilities. If mankind continues to depend on nuclear power generation systems in this century, it is imperative to establish sophisticated HLW disposal technologies that have high technical reliability and that are accepted by society.

(2) Frontier researches on science and technology

Researches on high-level radioactive waste disposal present remarkable characteristics as a part of the frontier researches that expand and strengthen the scientific and technological bases, and have far-reaching effects on other fields.

These researches include, for example, those on

Figure 2: Aspects of the high-level radioactive waste disposal problem



the structure, characteristics and very long-term changes in the deep geological environment, on the structures of atomic nuclei and the control of nuclear reactions, and on the designs and very long-term performance assessment methods of complex engineered systems involving many natural phenomena and physical and chemical reactions. Furthermore, much attention is directed to research and development projects using the most advanced beam science, including those for nuclear transformation technology using an accelerator. The next chapter will describe these researches in more detail.

(3) Repository sites and local symbiosis

Today, the repository site problem constitutes a major barrier to the implementation of high-level radioactive waste disposal projects. In many countries, the site selection processes for geological disposal or research facilities have faced opposition campaigns organized by the local governments and residents in the vicinities of candidate sites, as described in the previous chapter.

One of the recent striking moves regarding the problem of nuclear facility sites was the inhabitants' referendum adopted in the municipalities concerned. In Japan, inhabitants' referendum has been performed on the construction of a nuclear power plant (at Maki-cho in the prefecture of Niigata in 1996), the introduction of a plutonium thermal utilization system (at Kariwa village in the prefecture of Niigata in 2001) and the invitation of a nuclear power plant (at Miyama-cho in the prefecture of Mie in 2001), and the majority of the inhabitants voted against the respective projects.

For not only nuclear facilities, but also waste disposal facilities, dangerous matter handling facilities, military bases, etc., the site selection processes have encountered local residents' oppositions in the vicinities of the facilities. In some aspects, it may not always be appropriate to generalize the site problem of nuclear facilities into those of other facilities. However, efforts made toward solving the site problem faced by the nuclear power industry will probably provide valuable information necessary to build up a new social system in the 21st century, where science and technology will most likely continue to play important roles. These efforts will be further discussed in the chapter following the next.

(4) Non-proliferation of nuclear weapons and international cooperation

The problem of high-level radioactive wastes is related to nuclear substances management and nuclear weapons non-proliferation, and, as such, is delicate from the viewpoint of international politics. In countries such as Japan and France that adopted the policy line of recovering plutonium from spent fuels, there may be a low risk of nuclear weapons proliferation arising from high-level radioactive wastes themselves. However, these countries are required to establish a strict management system for the recovered amount of plutonium.

In countries such as the U.S. that adopted the direct geological disposal of spent fuels as high-level radioactive wastes in which plutonium remains, it is necessary to consider the risk of nuclear weapons proliferation due to theft or some other illegality during the period from the storage of spent fuels or wastes in ground facilities through the disposal and storage of wastes in the geological environment.

Furthermore, high-level radioactive wastes will be produced by the disposal of plutonium recovered from American and Russian surplus nuclear weapons as the nuclear weapons reduction process makes progress. The plutonium recovered from surplus nuclear weapons has a higher content of fissile plutonium, and, consequently, a higher risk of nuclear weapons proliferation than that in spent fuels recovered from commercial reactors. Especially, there is international concern about the management and disposal of plutonium recovered from Russian surplus nuclear weapons. At present, the Japan Nuclear Cycle Development Institute (JNC) is working with Russia to implement a joint disposal project for plutonium from surplus nuclear weapons by using the Russian breeder BN600.[10] In addition, international joint storage and disposal initiatives for radioactive wastes are being discussed in international conferences. However, it is more important for each country to make efforts in domestically disposing of radioactive wastes.[11]

8.5 Researches on geological disposal as a part of frontier researches on science and technology

As described in the previous chapter, many researches on geological disposal of high-level radioactive wastes are conducted as a part of the frontier researches that contribute to expanding and strengthening the scientific and technological bases. This chapter will discuss researches on the deep geological environment, nuclear transformation and control, and the coupled process system as some examples of frontier researches.

(1) Researches on the deep geological environment

Knowledge of the deep geological environment is the base on which a geological disposal system is built up from. However, the deep geological environment is unknown to mankind, as the deep sea and space are. Researches on the structure and environmental characteristics of the deep geological environment, as well as the flow of underground water, the influences of natural phenomena, etc., in this environment, are interesting as a part of the frontier researches.

The Japan Nuclear Cycle Development Institute (JNC) is implementing an underground research laboratory (URL) project (at Mizunami in the prefecture of Gifu) and the Horonobe URL project (at Horonobe in Hokkaido) targeting crystalline rocks and sedimentary rocks, respectively.[12] In these projects, various researches, for example, on the characterization of rocks and underground water, will be conducted in the exploratory drifts excavated at the depths of 500 to 1,000 m below the ground. It is expected that these underground research facilities will play the roles as places not only for the development of basic technologies for high-level radioactive waste disposal, but also for scientific exploration of the deep geological environment. The Nuclear Long-term Program[7] also states that the underground research facilities will be "constructed as open research places that can contribute to scientific researches on the deep underground environment in our country."

In the Horonobe URL project, one of the research themes is "Researches Using Underground Spaces." The JNC has a plan to invite local governments, external research organizations, companies, etc., to participate in this project, and to provide these underground research facilities for the participants to conduct tests and researches by using underground spaces.[13)] Most of the underground spaces now used are located in relatively shallow regions at the depth of about 50 meters below the ground, and it is estimated that there will be various needs for using these underground spaces. However, the JNC's plan is regarded as a unique attempt full of visions.

(2) Researches on nuclear transformation and control

Today, various industries are based on the atom- or electron-level reaction control technology. However, there is insufficient basic data even on the structures and reaction characteristics of atomic nuclei. Therefore, the utilization of nuclear reactions is limited to the nuclear power generation technologies and some radiation utilization technologies. In this sense, the world of atomic nuclei is unknown to mankind. Therefore, basic researches on atomic nuclei and the development of technologies using atomic nuclei have the potentiality of providing benefits to mankind.

The OMEGA (Options for Making Extra Gains from Actinides and Fission Products) project — a research project in which long-life nuclides are separated from high-level radioactive wastes and transformed into short-life or stable nuclides by using accelerators or nuclear reactors — was implemented in the 1990s. Thanks to the separation and transformation processes, the required period for the radioactivity levels of high-level radioactive wastes to become almost equal to that of uranium ore decreased from several tens to hundreds of thousands of years down to several hundred years.

Research on the nuclear separation and transformation processes is one of the research themes for the High-Intensity Proton Accelerator Project[14] jointly implemented by the Japan Atomic Energy Research Institute (JAERI) and the

Table 3: Main research themes for the high-intensity proton accelerator project [15]

Researches on matter and material sciences	• Development of new materials • Technological innovations and the creation of new industries • Explication of superconductivity at high temperatures
Researches on life science	• DNA decoding • Explication of genetic mechanisms • Analysis of protein structures • Development of new drugs and foods
Physical researches on atomic nuclei and elementary particles	• Explication of the mysterious birth of the cosmos • Researches on elementary particles as the smallest units of the cosmos • Explication of star formation processes • Creation of unknown new elements
Research on nuclear transformation	• Researches on radioactive waste reduction technologies

High-Energy Accelerator Research Institute (HEARI). Table 3 indicates the main research themes for this project.

In this project, the world's highest-level high-intensity proton accelerator facility will be constructed in the Tokai Research Center of the JAERI. This accelerator will produce a proton nearly at the speed of light. If the proton collides against a target nucleus, spallation will occur producing secondary grains such as neutrons, mesons, muons and neutrinos. The secondary grains will be used for a wide range of researches not only on the micro world made of biological molecules, atoms, elementary particles, etc., but also on the macro world including space and energy.

The "research on nuclear transformation technology," one of research areas in this project, will use the concept that spallation neutrons are radiated on long-life radioactive nuclides to transform them into short-life or stable nuclides. For this research, a plan has been set to start the construction of an experimental facility in the 2005 fiscal year. It is expected that this research will make great contributions not only to reducing the amount of high-level radioactive wastes, but also towards establishing the bases of nuclear transformation and control technologies.

(3) Researches on the coupled process System

The coupled process system is defined as a system that comprises of plural processes having influences on each other, and in which all the processes must be analyzed at the same time. This system has substantial properties specific to a complex system. Experimental researches on the coupled process system have limitations, because they must use many parameters having a high non-linearity. Researches have been conducted by digital simulation mainly on a fluid — structure or electromagnetic field — structure coupled process system. However, there are only a few research cases on coupled process systems comprising of three or more elements, because of the theoretical difficulty as well as restrictions on computer resources.

On the other hand, various coupled phenomena may occur in a geological disposal system, and it is necessary to analyze their behaviors for a very long period. To evaluate, for example, the deterioration rate of a waste package or the migration velocity of a radioactive nuclide in an engineered barrier system, it is necessary to simultaneously consider the thermal, hydrogeological, mechanical and chemical processes that have influences on each other in the geological disposal system as they are making progress. Literature 8 also points out that it is necessary to consider various events occurring in the drift of a repository, including chemical reactions, temperature variations, the alteration and corrosion of artificial materials, the pH of cement raised up by its partial dissolution, the changes of oxidation-reduction atmosphere and the associated production of colloid, in-crack minerals and zeolite, etc.

The Japan Nuclear Cycle Development Institute (JNC) has developed a model necessary to process the behaviors of a buried and re-submerged engineered barrier system as the coupled process of thermal migration, moisture migration and mechanical behaviors. In the future, JNC plans to promote the development of a heat-water-stresschemical reaction coupled process model by adding material migration and geochemical models to the first.[16]

Coupled phenomena may occur in various engineered systems, as the sodium leakage accident that occurred in the prototype fast breeder "Monju" in 1995 was caused by the coupled structure — fluid vibrations of a thermometer sheath and a coolant of sodium (hydrodynamic vibrations). It is expected that researches on high-level radioactive waste disposal will make great contributions to explicating the mechanism of coupled processes and developing effective system performance assessment methods and tools.

8.6 Toward solving repository site problems

The problem of high-level radioactive waste disposal has a variety of social aspects, as repeatedly described above. Today, the most important aspect is the site problem. This chapter focuses on this problem.

Site selection for nuclear facilities has had an increasing tendency of facing difficulties since the latter half of the 1980s. Researchers not only in the field of atomic energy, but also in the other fields such as administrative science, politics, socio-psychology and social information science have conducted a number of researches. Many of the researches conducted in recent years pointed out that it was important to disclose information to the public, ensure transparency, and involve citizens in the policy-making processes (public involvement).[17]

In recent years, the Japanese Government and nuclear power interests have made considerable efforts in promoting the disclosure of information and enhancing transparency. The 2000 Nuclear Long-term Program[7] also specifies: "all nuclear information should be disclosed to the public in principle, except that about nuclear material protection and others." In addition, information about discussions made on the national energy policy in organizations such as the General Science and Technology Council, the Atomic Energy Commission, the Nuclear Safety Commission and the Advisory Committee for Energy is now opened to the public, and the related materials such as proceedings are available on the Internet. Furthermore, the ministries and agencies as well as enterprises are making efforts to provide general nuclear information on their home pages and through other media.[18]

In regard to public involvement, a recent striking move is the collection of public comments. The collection of public comments on draft reports and other documents issued by the ministries and agencies as well as commissions and committees has been generalized since the Cabinet council set the "Public Commenting Procedure" in 1999. There has been an increasing number of cases where the representatives of consumer groups and NGOs as well as attorneys-at-law officially participate in the Government's commissions and committees. Inhabitants' referendum also may be considered as the ultimate form of public involvement. However, the legal status, effectiveness, appropriate subjects and method of inhabitants' referendum are still controversial among experts.

In the future, the Nuclear Waste Management Organization of Japan (NUMO) plans to select the "preliminary survey site", "site for detailed investigation" and "site for construction of the final repository" in turn (see Figure 3). The "Basic Policy for Final Disposal of Designated Radioactive Waste" decided by the Cabinet council in September 29, 2000 states that "it is imperative to obtain the related residents' understanding and cooperation in order to select the preliminary survey and other sites, and, to do so, it is necessary to thoroughly disclose relevant information to the public and ensure transparency." The Basic Policy for Final Disposal also specifies that it is necessary to diversify access to information, provide the requested information honestly, and make efforts to provide correct and understandable information.

The NUMO is also required: to prepare and inspect reports that contain the results of surveys, the justifications of selections and assessments, etc.; to organize briefings in the related prefectures including Tokyo the capital and Hokkaido; and to provide the public with opportunities to submit their comments on the reports. The NUMO plans to prepare a summary

Figure 3: Schedule of Works for Starting the Final Disposal [20]

Public invitation

(The final disposal schedule will start in 2002, as soon as the requirements are satisfied.)

↓

	Site Selection
1st phase	Studies of literatures and other materials ↓ Selection of preliminary survey site (Scheduled in 2003 to 2007)
2nd phase	Preliminary survey by a method such as boring ↓ Selection of site for detailed investigation (Scheduled in 2008 to 2012)
3rd phase	Preliminary surveys of underground facilities ↓ Selection of the site for construction of the final repository (Scheduled in 2023 to 2027)

↓

Design of repository / Safety review by the Government / Construction of repository

↓

Start of the final disposal

(Scheduled in 2033 to 2037)

of the submitted comments, send the copies of the summary, together with its own views, to the governors of the related prefectures and the heads of the related municipalities, and select the final preliminary survey site while considering the public's comments on the reports.[19]

As described above, it can be said that the environment for the disclosure of information and public involvement has been considerably established, though this is only one of the requirements to solve the site problem. The reasons why people are opposed to the selection of nuclear facility sites in their neighborhoods are entangled with complicated factors such as doubts about the safety of nuclear facilities, the lack of people's confidence in the related companies and nuclear power interests, and the political environment of the municipalities concerned. Furthermore, many have long pointed out the so-called NIMBY (Not in My Backyard) attitude where people resist the construction of any dangerous facility in the vicinity of their houses, though they recognize the necessity for such facility. However, it can be considered that this attitude is natural from the viewpoint of human feelings. How to coordinate individual and public interests in sites for worrisome facilities is a problem related to the foundation of a democratic society. In the future, it is important to make efforts in solving this problem.

8.7 Conclusion

This report has described the domestic and foreign trends of high-level radioactive waste disposal projects, reviewed the technical and social aspects of the problem, and discussed not only the possibility of conducting researches on high-level radioactive waste disposal as a part of the frontier researches that expand and strengthen the science and technology bases, but also efforts made in solving the site problem.

Repositories for high-level radioactive wastes are engineered systems by nature. However, people have a great interest in these repositories, and discussions have been made on these repositories from various viewpoints such as politics, laws, society, nuclear weapons non-proliferation, international relations, environmental harmony, and environmental ethics. The specifications and safety standards of these repositories cannot be decided only on the theoretical aspects. Finally, only a solution that is elaborated through discussions and modified through the different stages of the democratic decision-making process will be recognized by the public and validated.

In Japan, the first repository for high-level radioactive wastes is scheduled to start operation within the period of 2033 to 2037. To maintain the vitality and technical potentiality in the field of research and development related to this repository up to the scheduled time, it can be considered effective that active efforts are made in conducting not only researches directly related to this high-level radioactive waste disposal project, but also advanced basic researches making use of the accumulated results of researches and the expected far-reaching effects on the other fields. Some examples are the researches on the deep underground environment, nuclear transformation and control, and the coupled process system, as covered in this article.

The political and social situations involved in energy problems as well as people's awareness of safety and the environment may change with the times. Under these circumstances, it can be expected that the functional and safety requirements for high-level radioactive waste disposal systems will greatly change. To ensure that policies flexibly adaptable to the changing social environment can be implemented, it is essential to allocate research resources to R&D efforts on a variety of disposal options.

In recent years, administrative organs and other organizations have promoted the disclosure of nuclear information. The Government's commissions and committees also have largely collected and added public comments onto their reports and other documents. The representatives of consumer groups and NGOs as well as attorneys-at-law have generally participated in the related commissions and committees. Under these circumstances, it can be said that the conditions for citizens to participate in policy-making processes (public involvement) have been established considerably.

However, site problems have not yet been solved. The NIMBY problem involved in sites for worrisome facilities such as nuclear facilities is related to the fundamental part of a democratic society system. To solve this problem, it is required to adopt an interdisciplinary approach. Today, however, the opportunities for exchange are still limited between researchers in the disciplines such as humanities and social science, and those in the disciplines such as physics and engineering. To attract researchers from various disciplines in order to solve this problem, it is important that the societies in disciplines such as humanities and social science and those in disciplines such as physics and engineering provide interdisciplinary opportunities attractive to each other, take actions such as participation in the societies as qualified moderators, and promote the regular exchange of researchers between the interrelated disciplines.

In any event, it is expected that public arguments will continue to be made on the utilization of nuclear energy. Ultimately, however, the political leaders are required to establish their leadership and communicate adequately with citizens, based on their energy strategies after considering the results of scientific researches, domestic and foreign situations, and so forth.

References

[1] The National Institute of Scientific and Technological Policies, the Ministry of Education, Culture, Sports, Science and Technology: The 7th Technology Foresight (2001).

[2] Reproduced from the home page of the Japan Nuclear Cycle Development Institute (JNC).

[3] Reproduced from materials on the home page of the Nuclear Waste Management Organization of Japan (NUMO).

[4] "Basic Policy for Final Disposal of Designated Radioactive Waste" (decided by the Cabinet council on September 29, 2000).

[5] Japan Nuclear Cycle Development Institute (JRC): "H12: Project to Establish the Scientific and Technical Basis for HLW Disposal in Japan — Second Progress Report on Research and Development for the Geological Disposal of HLW in Japan" (1999).

[6] The Advisory Committee on the Nuclear Fuel Cycle Backend Policy, Japan Atomic

Energy Commission: “Assessment on the Technical Reliability of Research and Development for the Geological Disposal of High-Level Radioactive Wastes in Japan” (2000).
[7] Japan Atomic Energy Commission: “Long-Term Program for Research, Development and Utilization of Nuclear Energy” (“Nuclear Long-Term Program”) (2000).
[8] DOE: Viability Assessment of a Repository at Yucca Mountain, DOE/RW-0508 (1998).
[9] DOE: Final Environmental Impact for a Geologic Repository for the Disposal of Nuclear Spent Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada, DOE/EIS-0250 (2002).
[10] “Disposal of Plutonium from the Dismantlement of Russian Surplus Nuclear Weapons,” Atomic Energy Society of Japan, the General Report of the Annual Assembly in Spring 2002 (2002).
[11] Joint Declaration of International Conference on Geologic Repositories, Denver, October 31 – November 3 (1999).
[12] Japan Nuclear Cycle Development Institute (JNC): “Summary of Underground Research Laboratory (URL) Projects”, Briefing session on the research and development projects for HLW geological disposal technologies, January 2002.
[13] Horonobe Underground Research Center, Japan Nuclear Cycle Development Institute (JNC): Brochure “Outline of Underground Research Laboratory (URL) (tentative name).”
[14] Joint Implementation Team by the Japan Atomic Energy Research Institute and the High-Energy Accelerator Research Institute: High-Intensity Proton Accelerator Project, JAERI-Tech 2000-003 (KEK Report 99-5) (2000).
[15] Prepared from materials on the home page of the Japan Atomic Energy Research Institute.
[16] Gento Kamei: JNC TN1400 2001-017, 27-36 (2002).
[17] For example, Y. Tanaka, Is NIMBY Syndrome a Universal Phenomenon? Symptoms and Remedies, Gakushuin Review of Law and Politics, 35, 29-62 (1999).
[18] For example, the home page on radioactive wastes provided by the Ministry of Economy, Trade and Industry (http://www.enecho.meti.go.jp/rw/).
[19] Nuclear Waste Management Organization of Japan (NUMO): “Preliminary Policy for the Selection Procedure of the Preliminary Survey and Other Sites,” extra official bulletin, November 8, 2001.
[20] Prepared from materials on the home page of the Nuclear Waste Management Organization of Japan (NUMO).

(Original Japanese version: published in May 2002)